Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2016 Work Plan

Date of Report: December 4, 2015

Date of Next Status Update Report: January 1, 2017

Date of Work Plan Approval:

Project Completion Date: June 30, 2019

Does this submission include an amendment request? No

PROJECT TITLE: Solar Energy Utilization for Minnesota Swine Farms—Phase 2

Project Manager: Lee Johnston

Organization: University of Minnesota West Central Research and Outreach Center

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Location: Statewide

Total ENRTF Project Budget:	**ENRTF Appropriation:**	**$500,000**
	Amount Spent:	**$0**
	Balance:	**$500,000**

Legal Citation: M.L. 2016, Chp. xx, Sec. xx, Subd. xx

Appropriation Language:

(h) Solar Energy Utilization for Minnesota Swine Farms – Phase 2 *(ID: 149-E - Lee Johnston)*
$500,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota for the West Central Research and Outreach Center in Morris to continue to develop and evaluate the utilization of solar photovoltaic systems at swine facilities to improve energy and economic performance, reduce fossil fuel usage and emissions, and optimize water usage. This appropriation is available until June 30, 2019, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Solar Energy Utilization for Minnesota Swine Farms—Phase 2

II. PROJECT STATEMENT:

This project addresses an important question facing American pork producers, namely how to lower fossil energy use and reduce the carbon and environmental footprint of swine production systems. Minnesota has been a leader in addressing competing challenges within the nexus of food, environment, and energy. Pork producers need innovative housing systems that help address environmental and energy concerns while remaining competitive in the global market for pork. Minnesota is a major pork producing state (3rd nationally). The Midwestern climate dictates considerable indoor environmental (temperature) control of production facilities to ensure efficient production and comfort of pigs and workers. This environmental control includes heating (fossil fuels) during cold conditions and cooling (electricity) during warm/hot weather for all phases of pig production. Producers are seeking solutions to their energy use challenges. Helping producers find solutions to these challenges fits well with the ten-year goal of the Univ. of MN's West Central Research and Outreach Center (WCROC). That goal is to reduce fossil energy consumption and reduce the carbon and environmental footprint of Minnesota farms. This goal was established as part of a strategic planning process that identified rising energy costs and changing market demands for low carbon footprint agricultural products as key agricultural issues in the next decade. In applying this strategic goal to the problem facing the Minnesota pork industry, the research team identified two innovative methods to cool pigs that will lower ventilation rates and thus emissions of odor, greenhouse gases, and dust in exhaust air, reduce water usage, and lower the carbon and environmental footprint of Minnesota-produced pork. The first cooling system uses liquid-cooled pads located in farrowing stalls to cool the sows while they nurse their piglets during summer. Sows will lie on the pads and heat will be transferred from their body to the liquid contained within the pad. The second cooling system will provide chilled drinking water (55 °F) to sows in a farrowing facility. Sows provided cooled water drink less water, and are physically cooled by intake of the chilled water. Water cooling will be provided by a chiller or an air-source heat pump powered by solar PV collectors mounted on the roof of the sow facility. This project complements other ongoing state- and commodity-funded projects at WCROC that are investigating clean energy agricultural production systems.

III. OVERALL PROJECT STATUS UPDATES:

Project Status as of: January 1, 2017

Project Status as of: July 1, 2017

Project Status as of: January 1, 2018

Project Status as of: July 1, 2018

Project Status as of: January 1, 2019

Overall Project Outcomes and Results:

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Design, install, and evaluate a solar PV system and sow cooling pads in the farrowing facility

Description: The team will install a 20 kW solar PV collector and research the effective cooling of farrowing sows. Performance testing will be conducted over the course of Years 2 and 3. The electric energy generated from the solar PV system will be used primarily to power a water chiller / heat pump. The use of chilled water

will be evaluated as a means to cool sows using water jacketed floor pads that the sows lay upon. The solar powered cooling system will be designed using a combination of internal expertise and an external engineering firm. Commercially available floor pads will be installed in a farrowing room at the WCROC facilities and be connected to the water cooling system. Evaluation of the cooling pad system will be completed to determine improvements in performance and comfort of sows and their piglets in research over 2 summers. An engineering firm will assist the project team to model and design energy-efficient cooling systems that can be retrofitted into conventional swine facilities. Most of the swine facilities located in Minnesota have standardized design and construction. Therefore, retrofit designs can be utilized extensively across the state. The intent is to use an electric powered chiller / air-source heat pump to provide chilled liquid for the cooling systems. Heat pumps, especially air-source heat pumps, can be retrofitted to existing swine facilities. Heat pumps have a coefficient of performance of 2.5 meaning for every unit of energy put into the system, 2.5 units are available for use. Therefore, heat pumps could be a novel, energy saving feature for swine facilities. Cooling systems will be utilized that can also be incorporated into existing facilities. Interface control systems will be developed to effectively manage the novel cooling systems.

In the WCROC farrowing building, the project team will use either commercially-available or custom fabricated floor pad coolers within sow farrowing stalls and heat pumps to provide the cool, circulating fluid. Farrowing stalls are challenging to maintain proper temperature as a producer wants to keep the sows cool (about 60 ^{o}F) while keeping the piglets warm and dry (about 86 ^{o}F). Pad coolers utilize plates of steel with cooling loops attached to the underside which allow liquid to circulate. The pads are placed in the sow's stall and cool liquid is pumped through the cooling loops. Pad coolers will cool the sows through direct contact as the sow will lay across the pad and allow the piglets to remain warm in a separate, adjacent area. The liquid can then return to the heat pump where there is a transfer of the heat to the exterior air. The pad cooler covers about 30 to 50% of the sow's lying area and body. The farrowing building has two rooms with each containing sixteen individual sow farrowing stalls. Within one room, each sow will be cooled with a pad cooler and heat pump(s). The other room will be operated as the Control Treatment using conventional, forced-air ventilation cooling.

The project team will begin field testing by commissioning the systems without pigs in the rooms. In months 1 through 10, the cooling pads and chiller will be ordered and installed. Following installation, the system will be commissioned over the course of two months to insure proper performance during the sow trial. The commissioning process will include:

- Calibrating and refining controls
- Measuring liquid cooling temperatures
- Modeling heat transfer performance
- Troubleshooting

Once the system and controls are fine-tuned, pigs will be added to the buildings. Testing with pigs is anticipated to begin in the second year of the project.

In the farrowing building, sows will be allotted randomly to one of the two treatments: forced air ventilation cooling (Control Treatment - Room 1) or chiller / heat pump with pad cooler (Pad Cooling Treatment - Room 2). Animal performance variables measured will include: individual sow body temperature, sow feed intake, changes in sow weight and backfat depth, piglet and litter weight gains, and number of days from farrowing (birthing) to re-breeding. Amount of feed consumed daily by each sow will be recorded. Initial and ending (weaning date) sow weights will be recorded. Body temperature and respiration rates of the sows will be measured and utilized as an indicator of heat stress experienced by the sow. Following completion of the initial testing period, the study will be replicated at least once (if appropriate weather conditions allow) with a second set of sows to increase statistical confidence. Mechanical performance measures will include electrical energy consumption including power consumed by the heat pumps and ventilation fans which will be measured along with the outdoor, room, and cooling loop (fluid) temperatures. Air temperature and quality will be important metrics so variables measured will include: room temperatures, responsiveness of cooling systems in

maintaining setpoint temperatures, humidity levels, and concentrations of ammonia, hydrogen sulfide, carbon dioxide, methane, and nitrous oxide.

Outcomes will include information regarding energy savings and influences on pig performance. The information will then be used for the economic evaluation in Activity 3.

Reliability and durability of cooling systems are extremely important as equipment failure usually leads to compromised performance and in some situations could lead to death of a significant number of pigs. Swine production facilities are much harsher environments than office buildings with relatively high concentrations of dust, gases, and humidity, which increases the chances for physical damage to equipment. Typically, these undesirable components of air in the room are removed with exhaust air in a forced-air cooling system. Also, solar PV arrays may also be exposed to harsher than normal conditions at a swine production facility. To characterize reliability of the solar PV and cooling systems, the project team will measure operational availability, hours of operation, energy production (solar PV), and maintenance and repair events. This information will be incorporated into an extension bulletin and be used to refine cooling system pre-designs for swine farrowing facilities (Activity 3).

Summary Budget Information for Activity 1:

ENRTF Budget: $ 280,435
Amount Spent: $ 0
Balance: $ 280,435

Outcome	Completion Date
1. *Install solar PV collectors (20 kW) on the farrowing facility*	10/1/2016
2. *Design and install sow cooling systems including water-cooled pads for sows, heat pumps, and water delivery*	4/1/2017
3. *Field test and evaluate floor pad cooling for farrowing groups*	4/1/2019

Activity Status as of: January 1, 2017

Activity Status as of: July 1, 2017

Activity Status as of: January 1, 2018

Activity Status as of: July 1, 2018

Activity Status as of: January 1, 2019

Final Report Summary:

ACTIVITY 2: Design, install and evaluate chilled drinking water system for pigs

Description: A second option to cool sows is to provide cool drinking water. Even though this seems to be obvious, initial testing has shown that drinking water in conventional farrowing facilities can warm up significantly and contribute to overheating animals. So chilling and recirculating the drinking water may be an effective approach to maintaining sows within their thermal neutral comfort zone. When sow body temperatures climb above the thermal neutral comfort zone, feed efficiency, reproductive performance, and litter performance can decline significantly.

In this activity, a cooling system that supplies chilled drinking water to sows will be designed by the project team and external consulting engineers. The team anticipates using the same chiller / heat pump used in Activity 1 to chill the drinking water. The system will be installed and evaluated in the farrowing building at WCROC. The system will be evaluated for its ability to provide chilled water consistently and reliably to sows over the two years of the project. Economic feasibility of the system will be determined considering costs of equipment, installation (including insulating water lines), maintenance, operation, and performance of sows. Electricity from the solar PV array will be used to power the system. Sows will be allotted randomly to one of the two treatments: conventional drinking water (Control Treatment - Room 1) or chilled drinking water (Chilled Water Treatment - Room 2). Animal performance variables measured will include: individual sow body temperature, sow feed intake, changes in sow weight and backfat depth, piglet and litter weight gains, and number of days from farrowing (birthing) to re-breeding. Amount of feed consumed daily by each sow will be recorded. Initial and ending (weaning date) sow weights will be recorded. Body temperature and respiration rates of the sows will be measured and utilized as sensitive indicators of heat stress experienced by the sow. Following completion of the initial testing period, the study will be replicated at least once (if appropriate weather conditions allow) with a second set of sows to increase statistical confidence. Water temperature of the system will be measured for both the control and chilled water treatments. Temperature of the drinking water will be measured as it enters the building, after chilling (chilled water treatment), and at various points within the farrowing room. Energy consumed in chilling the drinking water will be measured.

Summary Budget Information for Activity 2:

ENRTF Budget: $139,434
Amount Spent: $ 0
Balance: $ 139,434

Outcome	Completion Date
1. *Design and install a chilled drinking water system in the sow farrowing facility*	4/1/2017
2. *Field test and evaluate the chilled drinking water system in the sow farrowing facility*	4/1/2019

Activity Status as of: January 1, 2017

Activity Status as of: July 1, 2017

Activity Status as of: January 1, 2018

Activity Status as of: July 1, 2018

Activity Status as of: January 1, 2019

Final Report Summary:

ACTIVITY 3: Perform economic analysis and disseminate results of system evaluations

Description: A basic cost-benefit analysis will be developed comparing the conventional and energy-optimized systems. Basic economics will be evaluated in terms of capital expense, operational and maintenance costs, pig performance, and energy savings. A closeout spreadsheet model will be developed for the farrowing treatments. The spreadsheet will include the capital and operating costs from each system and will project simple payback using performance information observed during the farrowing facility trials. A spreadsheet will be developed for swine producers so they can model their own potential return on investment for the energy-

efficient cooling system retrofits. The results of the study will be transferred to swine producers through a variety of methods including presentations and tours at the Midwest Farm Energy Conference in Summer 2017 focusing on swine production facilities, development of an extension bulletin, a dedicated web page, news articles in agricultural magazines, summaries on the University of Minnesota Extension Swine webpage, peer-reviewed publications, and through presentations to swine producers at industry meetings. The information will be incorporated into an extension bulletin and be used to refine cooling system pre-designs for swine farrowing facilities. Finally, a "virtual" video tour will also be produced so that swine producers can see the systems without physically entering the building. Swine farmers are extremely wary of inadvertently transferring swine diseases from one farm to another. Consequently, many swine farmers will not visit other swine farms to avoid transmission of disease. The video tour will allow us to share our results with producers that are not willing or able to visit our research site in person.

Summary Budget Information for Activity 3:

ENRTF Budget: $80,131
Amount Spent: $ 0
Balance: $ 80,131

Outcome	Completion Date
1. *Produce a "virtual" tour of the solar PV and sow cooling systems for use in outreach activities.*	1/1/2019
2. *Perform a basic economic analysis on the solar PV and sow cooling systems.*	4/1/2019
3. *Develop an extension bulletin with results as well as pre-design examples for the solar PV and sow cooling systems that producers may use as guides. The extension bulletin will be printed and placed on-line.*	4/1/2019
3. *In each of the first two years of the project, the project and preliminary results will be discussed at 3 or more producer / professional meetings. In Year 3, the team will organize three informational meetings in key swine production areas of Minnesota.*	6/1/2019

Activity Status as of: January 1, 2017

Activity Status as of: July 1, 2017

Activity Status as of: January 1, 2018

Activity Status as of: July 1, 2018

Activity Status as of: January 1, 2019

Final Report Summary:

V. DISSEMINATION:

Description: Results of this project will be disseminated through several methods. In summer 2017, the West Central Research and Outreach Center will host the Midwest Farm Energy Conference. Attendees expect to include livestock producers, energy professionals, students and other stakeholders. At the conference, results of this project will be presented and there will be a tour of the solar energy systems at the WCROC Swine Research Unit (as long as biosecurity protocols can be met). Initial results will be discussed at three or more meetings with swine producers, swine industry professionals, or energy professionals in each of the first two years of the project. In Year Three, the project team will organize three informational meetings in key swine production areas of Minnesota. The meetings will focus on disseminating the results to swine producers and the professionals that consult with swine producers. The results will also be disseminated on-line on the WCROC

website as well as the University of Minnesota Swine Extension Team website. An extension bulletin with the project results and retrofit pre-designs will be printed and provided to swine producers and other stakeholders. A virtual video tour of the cooling and solar systems will also be produced. This video will allow swine producers to limit their exposure to an operating swine facility and the swine diseases that might be associated with that particular farm. This video will greatly extend the reach of our project by letting more farmers see the system without the biosecurity risks and travel requirements necessary to view the systems in person. The video will also be posted on our websites which further extends the distribution of our outcomes. We also anticipate publishing results in academic journals, local and regional newspapers, and industry magazines.

Status as of: January 1, 2017

Status as of: July 1, 2017

Status as of: January 1, 2018

Status as of: July 1, 2018

Status as of: January 1, 2019

Final Report Summary:

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Overview Explanation
Personnel:	$ 234,226	Staff to coordinate project, collect and organize data, and assist in disseminating results including: Project Coordinator at 0.4 FTE Yr 1 and 0.5 FTE Yr 2 and 3 ($97,232); 4 Student interns Yr 2 & 3 ($22,864); Junior Scientist Yr 2 ($52,137); Research Fellow 0.5 FTE Yr 1 and 0.24 FTE Yr 2 ($61,993)
Professional/Technical/Service Contracts:	$ 99,000	Contracts for engineering design and system installation including: $30,000 for engineering professional services, $35,000 for General Contracting of Cooling System installation, $21,000 for General Contracting of Solar PV installation, $3,000 for Mechanical Contractor for Energy Sensor and Meter installation, and $10,000 for Control System installation. These professional services will be bid through a RFP process following University of Minnesota purchasing policy.
Equipment/Tools/Supplies:	$ 9,000	Energy and temperature sensors for sow facilities and animals including the potential for approximately 32 electronic temperature sensors for sows, 64 water temperature sensors, 12 electrical current sensors and data loggers.

Capital Expenditures over $5,000:	$ 137,000	Chiller / air source heat pump to cool water ($50,000), 20 kW solar PV system and cooling systems for sow farrowing facilities ($67,000), Controls for sow and water cooling systems ($20,000)
Fee Title Acquisition:	$NA	
Easement Acquisition:	$NA	
Professional Services for Acquisition:	$NA	
Printing:	$ 3,600	Printing of an extension bulletin to disseminate to swine producers, their consultants, and energy professionals (300 copies @ $12 each)
Travel Expenses in MN:	$ 5,465	Travel from Saint Paul to Morris to setup experiments and to collect data (10 trips, 330 miles each, $.565/mi). Travel to regional, in-state swine producer meetings to disseminate results (At least nine total trips @ $400 each including mileage, room, and meals).
Other:	$ 11,709	Development of a video for a virtual tour of solar PV and cooling systems within the sow farrowing facility (Important for biosecurity as producers are hesitant to tour other swine facilities in-person)
TOTAL ENRTF BUDGET:	**$ 500,000**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000:
The University of Minnesota West Central Research and Outreach will purchase a 20 kW solar photovoltaic system ($67,000) which will produce electricity for the on-site sow farrowing facility. Energy production, availability, and other variables important to economic feasibility will be measured. In addition, the solar PV system will be used to power sow cooling systems including a chiller / heat pump. The chiller / heat pump will be installed within the sow farrowing system and produce chilled water for the sow cooling pads and chilled drinking water. The cooling system will cost approximately $50,000. The sow cooling systems will need dynamic control capabilities to measure and adjust temperature so a control system will be purchased ($20,000). Funding for installation of these components is included in the Contract budget line.

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation:
Averages 1.2 FTE per year over three years. Cumulative FTE 3.64

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: Approximately 2.4 FTE total (year 1).

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
U of MN Indirect Cost Recovery / In-kind	$132,600	$	Indirect costs associated with normal operation of the University of

			Minnesota will be used as in-kind cost share.
State			
	$	$	
TOTAL OTHER FUNDS:	**$132,600**	**$**	

VII. PROJECT STRATEGY:

A. Project Partners:

Dr. Lee Johnston, U of MN WCROC Director of Operations and Swine Scientist, will serve as the principle investigator and project manager. He will be responsible for all reports and deliverables. Dr. Larry Jacobson (U of MN Agricultural Engineer) will be a co-investigator and provide guidance on cooling system designs and testing in the swine facilities. He will also participate in the outreach activities. Mike Reese (WCROC Renewable Energy Director) will serve as a co-investigator and assist in the design, installation, testing, and control strategies of the solar energy portions of the cooling systems. He will also assist in coordinating with other ongoing energy projects at WCROC and help disseminate results. An engineering firm will be solicited through a RFP and will provide consulting services for designing, commissioning, and control strategies. An agricultural economist (yet to be named) will assist in the economic analysis of the solar systems.

B. Project Impact and Long-term Strategy:

The WCROC has a 10-year strategic plan to reduce consumption of fossil fuel and reduce the carbon and environmental footprint within production agriculture. This proposal builds upon current projects including 2014 ENTRF funding for the solar PV system on the WCROC grow-finish swine facility, energy audit, and modeling ($500,000). Long-term funding will continue to be sought to research alternatives to fossil energy within all agricultural crop and livestock enterprises through federal, state, and stakeholder groups.

C. Funding History:

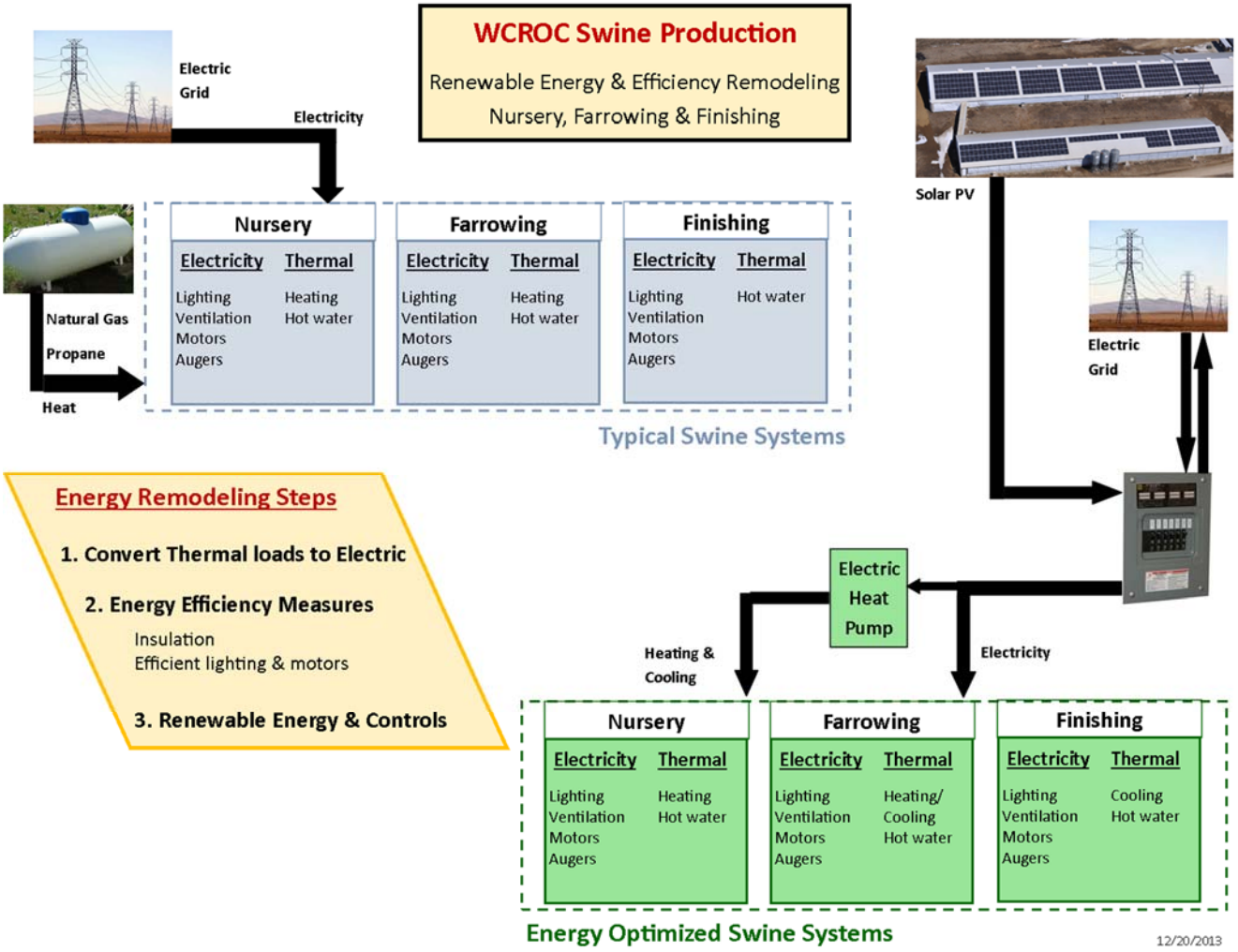
Funding Source and Use of Funds	Funding Timeframe	$ Amount
2014 ENTRF – Phase 1 – "Transitioning Minnesota Farms to Clean Energy" to audit energy consumption in conventional swine production facilities, model optimal clean energy systems, and evaluate performance	July 2014 to June 2017	$500,000
University of Minnesota College of Food, Agricultural, and Natural Resource Sciences for additional research support to develop and evaluate clean energy systems for agricultural production systems including crop (feed), dairy, and swine production	July 1, 2013 to June 2015	$167,061
University of Minnesota Initiative for Renewable Energy and the Environment – Establishment of baseline energy consumption of dairy and crop / feed production systems	Through January 2016	$350,000

VIII. FEE TITLE ACQUISITION/CONSERVATION EASEMENT/RESTORATION REQUIREMENTS: Not applicable

IX. VISUAL COMPONENT or MAP(S):

Environmental and Natural Resources Trust Fund
2016 Visual Graphics
Project Title: Solar Energy Utilization for Minnesota Swine Farms—Phase 2

Graphics 1. Schematic representation of the energy-optimized WCROC swine facilities



The project team has received past funding from the Environment and Natural Resources Trust Fund to audit energy consumption and install a 27 kW solar photo voltaic system for the WCROC swine facilities. Funding is being requested from LCCMR in this proposal to install a second 20 kW solar photo voltaic system. These two solar electric generation systems will provide electricity for their respective buildings. The primary purpose of

this proposal is to develop effective uses for the solar power generated on swine farms. So therefore, additional funding is being requested to evaluate and optimize the local use of the solar energy on Minnesota swine farms by installing electric heating and cooling systems within the facilities. Using novel solar electric-powered heating and cooling systems will enable the increased utilization of locally-produced renewable energy and have the added potential to lower ventilation rates and thus emissions of odor, greenhouse gases, and dust in exhaust air, reduce water usage, and lower the carbon footprint of Minnesota-produced pork.

X. RESEARCH ADDENDUM: Not applicable

XI. REPORTING REQUIREMENTS:

Periodic work plan status update reports will be submitted no later than January 1, 2017; July 1, 2017; January 1, 2018; July 1, 2018; and January 1, 2019. A final report and associated products will be submitted between June 30 and August 15, 2019.

Environment and Natural Resources Trust Fund
M.L. 2016 Project Budget

Project Title: Innovative Solar Energy Utilization for Minnesota Swine Farms
Legal Citation: *Fill in your project's legal citation from the appropriation language - this will occur after the 2016 legislative session.*
Project Manager: Lee Johnston
Organization: University of Minnesota West Central Research and Outreach Center
M.L. 2016 ENRTF Appropriation: $ *500,000*
Project Length and Completion Date: 3 *Years, June 30, 2019*
Date of Report: December 4, 2015

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	Activity 3 Budget	Amount Spent	Activity 3 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Install/ evaluate solar PV & sow cooling***			***Install/ evaluate chilled sow drinking water***			***Perform economic analysis & outreach***				
Personnel (Wages and Benefits)	$86,502		$86,502	$86,502		$86,502	$61,222		$61,222	$234,226	$234,226
Eric Buchanan, Project Coordinator: $97,232 (.4 FTE Yr 1, .5 FTE Yrs 2 & 3) 72.6 % Salary and 27.4% Fringe Rate											
Junior Scientist, Technician for data collection, system testing: $52,137 (1 FTE Yr 2) 72.6 % Salary and 27.4% Fringe Rate											
Brian Hetchler, Research Fellow, Facilility data collection and testing: $61,993 (.5 FTE Yr 1, .24 FTE Yr 2) 72.6% salary and 27.4% Fringe Rate											
Undergrad Student Interns to evaluate Clean Energy Technology for MN Swine Farms as well as help with Economic Analysis: $22,864 (2 summer interns each in Yrs 2 & 3) 100 % Salary and 0% Fringe Rate											
Professional/Technical/Service Contracts											
AKF Engineering (or equivalent firm) - Professional design and commissioning engineering services. AKF Engineering is working on past phases. Contracts will be bid /awarded based on U of MN purchasing policy.	$22,000		$22,000	$8,000		$8,000				$30,000	$30,000
General Contractor TBD - Installation of Cooling Systems. Contracts will be bid /awarded based on U of MN purchasing policy.	$20,000		$20,000	$15,000		$15,000				$35,000	$35,000
General Contractor TBD - Installation of Solar PV Systems Contracts will be bid /awarded based on U of MN purchasing policy.	$21,000		$21,000							$21,000	$21,000
Mechanical Contractor TBD - Installation of energy and temp meters / sensors. Contracts will be bid /awarded based on U of MN purchasing policy.	$1,500		$1,500	$1,500		$1,500				$3,000	$3,000
Mechanical Contractor TBD - Installation of control systems in swine facilities. Contracts will be bid /awarded based on U of MN purchasing policy.	$7,000		$7,000	$3,000		$3,000				$10,000	$10,000
Equipment/Tools/Supplies											
Sensors and Meters - For measurement of energy consumption and temperature in swine facilities and in animals (temperature only).	$4,500		$4,500	$4,500		$4,500				$9,000	$9,000
Capital Expenditures Over $5,000											

Chillers / Air Source Heat Pump(s) and Cooling Pads for Swine Farrowing Facility	$38,000		$38,000	$12,000		$12,000				$50,000	$50,000
20 kW Solar Photovoltaic System for Swine Farrowing Facility	$67,000		$67,000							$67,000	$67,000
Controls for Pad and Chilled Water Cooling Systems	$12,000		$12,000	$8,000		$8,000				$20,000	$20,000
Fee Title Acquisition											
Easement Acquisition											
Professional Services for Acquisition											
Printing											
Printing of outreach materials / extension bulletin for swine producers and energy / swine facility professionals (engineers, etc) - 300 @ $12 ea							$3,600		$3,600	$3,600	$3,600
Travel expenses in Minnesota											
Ten trips by Jacobson / Hetchler from St. Paul to Morris (330 miles @ $.565 /mi	$933		$933	$932		$932				$1,865	$1,865
In-state travel by project team to regional outreach events and meetings (At least 3 events per year)							$3,600		$3,600	$3,600	$3,600
Other											
Virtual Tour of Swine Facilities - A video will be made of the innovative solar systems and the cooling systems that are implemented. A video is important due to biosecurity concerns with visitors entering swine facilities. This video may be produced by the University or an outside vendor.							$11,709		$11,709	$11,709	$11,709
COLUMN TOTAL	**$280,435**		**$280,435**	**$139,434**		**$139,434**	**$80,131**		**$80,131**	**$500,000**	**$500,000**

M.L. 2014 122-E "Transitioning Minnesota Farms to Local Energy"	**M.L. 2016 149-E "Solar Energy Utilization for Minnesota Swine Farms – Phase 2"**
This first phase establishes baseline energy consumption data at University and commercial swine production facilities. The project begins to address the use of renewable energy within University swine finish facilities and also begins to measure the life cycle energy and carbon footprint of swine production (baseline compared with modeled energy improvements).	This second phase looks specifically at swine farrowing facilities and better utilizing renewable energy generation. The energy generated with a solar PV system will be used to power optimized cooling systems for sows that are nursing piglets. This stage of swine production is key in that considerable energy is consumed within challenging conditions. Based on initial results of Phase 1, considerable improvement can be made in energy utilization, environmental impact, sow comfort and well-being, and farmer profitability. The Phase 2 research will implement and test these improvements.
1. Measure energy consumed within University and commercial swine production facilities across production stages to establish baseline values.	1. Install a solar PV system on the **University sow farrowing facility (building #2).**
2. Use baseline energy consumption data to model and evaluate improved energy use and production. From the model, we can project return-on-investment for various energy retrofits. Design a clean-energy system for the University swine finishing barn (solar PV system)	2. Install water-jacketed pads within sow pens that will cool the sows while the nearby piglets are able to remain warm. Energy generated from the solar PV system will be used to power a chiller and pump to cool the sows. We expect that fans typically used for air cooling can be turned down which will conserve energy. Energy savings and animal performance will be measured.
3. Install a solar PV system on the **University swine finishing building (building #1)** to establish production and other key data.	3. Install a system to chill drinking water for sows within the farrowing facility. Initial phase one data has shown the temperature of drinking water within sow facilities can become very warm. Chilled drinking water has been shown to help cool pigs in other studies. Again, the same solar PV system, chiller, and pumps will be used to chill the drinking water. Trials will be performed to identify the energy savings and animal performance of these two individual cooling systems as well as the combined impact.
4. Perform Life Cycle Assessment of the Swine Production Systems utilizing energy data measured within this project.	4. An economic analysis will be performed of the solar PV system combined with the cooling systems within the **sow farrowing facility**. The new data from Phase 2 will be added to the Life Cycle Assessment completed in Phase 1.
5. Disseminate information to producers.	5. Disseminate Phase 2 results to producers.